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Feasibility of bi-culture of mud crab (*Scylla serrata*) and shrimp (*Penaeus monodon*)

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Abstract
A study on the feasibility of bi-culture of mud crab (*Scylla serrata*) and shrimp (*Penaeus monodon*) in brackishwater earthen ponds (0.1 ha each) was carried out for a period of five months (March-August). Nursed shrimp juvenile (ABL: 3.36±0.23 cm and ABW: 0.26±0.04 g) and crab juvenile (ACL: 2.61±0.22 cm, ACW: 4.63±0.11 cm and ABW: 43±2.64 g) were stocked following the experimental design of shrimp $2/m^2$ (Treatment-1), shrimp $2/m^2$ and mud crab $1/m^2$ (Treatment-2) and shrimp $2/m^2$ and mud crab $0.5/m^2$ (Treatment-3). Crabs were fed with chopped trash tilapia @ 10~5%, while shrimp were fed with Saudi-Bangla shrimp feed @ 3~5% of biomass twice daily. Significantly ($p<0.05$) higher specific growth rate (SGR) of shrimp and mud crab was 1.86% (g/day) in T2 and 0.83% (g/day) in T3, respectively. The survival of shrimp and mud crab also varied significantly ($p<0.05$) with a higher mean value of 74.63% in T1 and 51.04 % in T3, respectively. The production of shrimp (424.09 kg/ha) was significantly ($p<0.05$) higher in T1 and that of mud crab (568.80 kg/ha) in T2. Significantly ($p<0.05$) highest total production of 871.29 kg/ha was in T2 followed by 708.52 kg/ha in T3 and 424.09 kg/ha in T1. The results indicate that mud crab can be cultured at a stocking rate of $1/m^2$ together with shrimp at $2/m^2$.

Key words: Mud crab, Tiger shrimp, Bi-culture

Introduction

Among mud crab, *Scylla serrata* is the most commonly cultured species due to its preference for estuarine habitat, less aggressive behaviour and higher value (Cowan 1984). With declining catches, following overfishing and possibly widespread clearing of mangroves (the natural habitat of the mud crab), and increasing consumer demand, monoculture, polyculture and fattening of crabs have been becoming popular in Southeast Asian countries. Crab culture and fattening are, however, still in the experimental stage in South Asia (Samarasinghe *et al.* 1992).

Mud crab culture has evolved from low density pond polyculture with fish, using wild seeds introduced tidally or intentionally, to monoculture in smaller ponds, pens and cages (Cholik and Hanafi 1992). In Philippines, the species has been cultured in ponds (Samonto and Agbayani 1992, Trino *et al.* 1999) as well as in pens (Baliao *et al.* 1999). The crab farming in Taiwan is based mainly on polyculture where shrimp (*P. monodon*), milkfish (*Chanos chanos*) and mullets are commonly cultured together with crabs (*S. serrata*), in combinations of two, three or four species (Cowan 1984). Possibility of the polyculture of milk fish, mullets and shrimps with crabs has also been explored elsewhere (Fitzgerald 1997, Mwaluma 2002).

In Bangladesh, *S. serrata* is the most important species in coastal fisheries, particularly for trade next to shrimp. Bangladesh has been earning a lot of foreign currency every year by exporting mud crab to the international market. The species is extensively grown in coastal impoundments together with shrimp (Giasuddin and Alam 1991) and in mangrove tidal flats (Kador 1991). Though the crab fattening practices are in place in some coastal areas of the country, crab fatteners have to rely on natural catch for supply of suitable sized crabs to fatten. Despite the economic value and high demand in the world market, no attempt has so far been reported in the country in developing the culture technology of this crab species either alone or together with shrimp and other suitable fish species. Pond culture of crab is mostly of a subsistence nature and is generally a part-time operation. Development of mud crab polyculture in brackishwater ponds, therefore, might be an alternative effort for booming the production levels and improvement of coastal livelihoods. Considering the above in view, the present research has been conducted with an aim of determining the growth, survival and production performance of mud crab *S. serrata* and shrimp (*P. monodon*) in a bi-culture system.

Materials and methods

The experiment was conducted in the earthen ponds of Bangladesh Fisheries Research Institute (BFRI), Brackishwater Station, Paikgacha, Khulna from the period of March-August 2007. Nine ponds having an area of 0.1 ha each were prepared through sun drying and liming the bottom soil with agricultural lime @ 250 kg/ha and mustard oil cake @ 500 kg/ha. The insides of pond embankment one meter apart from the edge of water were encircled with bamboo split-made fence so that crabs could not be able to escape in any way. The ponds were filled in with tidal water up to a depth of 1 m and inorganic fertilizers of TSP and urea were applied @ 35 kg/h with 3:1 ratio.

After 10 days of fertilization, shrimp (*P. monodon*) juvenile (ABW: 0.26±0.04 g) that were nursed in hapa nursery system and juvenile of crab (ACL: 2.61±0.22 cm, ACW: 4.63±0.11 cm and ABW: 43±2.64 g), which were collected from the Sundarbans mangrove area through fishermen, were stocked in the ponds following different stocking patterns of (i) shrimp 2/m^2 (Treatment-1), (ii) shrimp 2/m^2 and mud crab 1/m^2 (Treatment-2) and (iii) shrimp 2/m^2 and mud crab 0.5/m^2 (Treatment-3). Each treatment had three replications and those were assigned into a completely randomized design. Prior to stocking crabs were acclimatized for about 30 minutes and the male female ratio at each stocking density was Male: Female 1:9.

The juvenile crabs were fed twice a day with tilapia fish @ 5~10% and shrimps were fed with Saudi-Bangla shrimp feed @ 3~5% of the biomass. About 50% of water was exchanged with tidal water at every new and full moon throughout the experimental period. Growth performance of crabs in respect of carapace width (CW), body weight (BW) and that of shrimp in respect of body length (BL) and body weight (BW) were recorded fortnightly. Physico-chemical parameters of pond water, *viz.*, temperature, transparency, salinity, pH, and dissolved oxygen were also recorded fortnightly following standard measurement procedures

(APHA 1992).

After four months of rearing shrimps were harvested by cast netting and after five months, crabs were harvested, along with any left over shrimp, by draining out the pond water. Growth (final length, width, weight), specific growth rate (SGR), survival and production of shrimps and crabs were estimated at harvest. ANOVA was done to observe any difference in growth parameters of both shrimp and crabs and Duncan's New Multiple Range Test (DNMRT) was also employed for further analysis of the results.

Results and discussion

Water quality parameters

Mean values of different water quality variables are shown in Table 1. There was no significant difference ($p>0.05$) in any of the parameters among the treatments. The temperature of water varied within the range of 24~32°C, which is similar that has been reported suitable for both crab (Cholik and Hanafi 1992, Baliao *et al.* 1999) and shrimp (Milstein *et al.* 2005). During the study period, a wide range of 2~16 ppt salinity was observed, with highest in June and lowest in mid August, but difference among the treatments was not significant. The fall in salinity was due to monsoon rain. Though Cholik and Hanafi (1992) reported that 10-25 ppt salinity is optimal for the growth of mud crab and Bhuiyan and Islam (1981) reported 10 ppt as the lower and 50 ppt as the upper lethal salinity for crab, Mia *et al.* (2007) reported satisfactory growth and production of mud crab within the salinity range of 3~16 ppt. In case of shrimp culture, the observation on salinity in the present trail is strongly supported by the observations of Shaha *et al.* (1999) and Milstein *et al.* (2005).

Table1. Mean (±SD) values of different water quality variables in ponds under different treatments (S= shrimp, C= crab)

Parameters	S-2/m^2 (T1)	S-2/m^2:C-1/m^2 (T2)	S-2/m^2:C-0.5/m^2 (T3)
Temperature (°C)	26.62±2.15	26.26±1.59	26.46±1.38
Salinity (ppt)	11±3.34	10.40±4.27	10.6±4.52
pH	8.54±0.39	8.82±0.34	8.64±0.46
DO (mg/l)	5.88±0.53	5.12±0.57	5.44±0.09
Transparency (cm)	33.4±2.15	35.4±1.6	32.6±5.34

Values for all water quality variables among the treatments are insignificant ($p>0.05$).

The pH values in the present trail were within the range of 8.5~8.8. The pH values of 8.0~8.4 were recorded in case of mud crab culture by Mia *et al.* (2007), but are also congenial for shrimp culture and strongly supported by the findings of New (1995) and Milstein *et al.* (2005). Dissolved oxygen (DO) and water transparency were recorded within a range from 5.15~6.69 mg/l and 26~38 cm, respectively. DO values remained above sub-optimal levels (>4g/l), avoiding environmental stress for shrimp (Chanratchakool *et al.* 1995). Variations in dissolved oxygen of 5.31~5.92 mg/l and transparency of 28~35 cm, which have been recorded for mud crab culture (Mia *et al.* 2007), are more or less similar to the present study.

Growth and production

Growth and production values (mean±sd) of shrimp and mud crab under three different treatments are furnished in Table 2. While the average final body weight of shrimp (36.14±2.61g) was found significantly higher ($p<0.05$) in T2, that of mud crab was similar ($p>0.05$) in T2 (137.80±7.96 g) and T3 (151.09±5.46 g). Similar to final body weight gain, the SGR of shrimp was significantly ($p<0.05$) higher in T2, but similar ($p>0.05$) in T1 and T3. The lower final body weight of shrimp in T1 might have been due to the significantly ($p<0.05$) with a higher mean value survival rate of 74.63 ±7.27%. It is interesting to note that, in spite of the variation in stocking density of crab, the survival rates of shrimp was similar ($p>0.05$) in T2 and T3. However, both SGR and survival rate of crabs were significantly lower in T2, i.e. at the higher stocking density of 1/m^2 (Table 2).

Table 2. Growth and production values (mean±sd) of shrimp (S) and mud crab (C) under different treatments

Variables	Treatment-1	Treatment-2		Treatment-3	
	S: 2/m^2	S: 2/m^2	C: 1/m^2	S: 2/m^2	C: 0.5/m^2
Initial length (cm)	3.36±0.23	3.36±0.23		3.36±0.23	
Final length (cm)	16.50±1.14	17.18±0.18		17.07±0.57	
Initial weight (g)	0.26±0.04	0.26±0.04		0.26±0.04	
Final weight (g)	28.5±1.41^{b}	36.14 ±2.61^{a}		31.03± 1.05^{b}	
Initial CW (cm)			4.63±0.11		4.63±0.11
Final CW (cm)			8.66±0.27$_{a}$		8.93±0.57$_{a}$
Initial BW (g)			43±2.64		43±2.64
Final BW (g)			137.80±7.96^{a}		151.09±5.46^{a}
SGR% (g/day)	1.67±0.03^{b}	1.86±0.06^{a}		1.74±0.03^{b}	
SGR% (g/day)			0.77±0.03^{b}		0.83±0.01^{a}
Survival rate (%)	74.63±7.27^{a}	42.18±7.15^{b}		52.13±2.42^{b}	
Survival rate (%)			41.14±1.98^{b}		51.04±2.20^{a}
Production (kg/ha)	424.09±3.49^{a}	302.48±3.38^{b}		323.27±9.68^{b}	
Production (kg/ha)			568.80±8.07^{a}		385.37±3.92^{b}
Total Production (kg/ha)	424.09±3.49^{b}	871.29± 10.5^{a}		708.52±11.78^{a}	

Values in the same row with dissimilar superscripts are significantly different ($p<0.05$).

The survival rates of crabs at 0.5/m^2 and 1/m^2 has been found supportive to what has been reported by Samarasinghe *et al.* (1992) as 44.27 % at a stocking density of 0.6/m^2 for a grow-out period of 115 days. The result of the present experiment regarding the final weight gain in crabs has been found comparable to Allan and Fielder (2004), who stocked juvenile crab in a disused prawn pond at 1, 2 and 5/m^2, fed trash fish, snails and clams at 3% B.W/day, and recorded an average weights were 146, 159 and 158g, respectively. Growth increment of shrimp and mud crab, in respect to body weight (BW), throughout the culture period is shown in Fig. 1 and Fig. 2, respectively. The higher body weight increment of crab in T3, compared to that in T2, might be due to the lower stocking density. The increment in body weight of crab increased sharply from May and continued up to the end of the culture period (Fig. 2), but that was slow at the later end with the commencement of monsoon rain that resulted in drop of water salinity. Shrimps in monoculture (T1) always had lower growth increment (Fig. 1) than in bi-culture treatments. This might be due to the higher survival rates of shrimp in T1 (74.63±7.27%) than in T2 (41.14±1.98%) and T3 (51.04±2.20%).

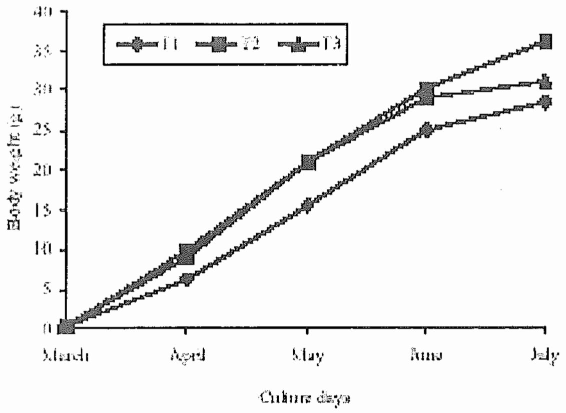

Fig. 2. Body weight increment of mud crab in bi-culture system.

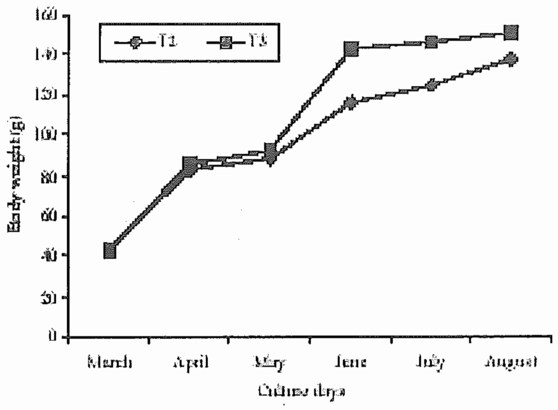

Fig. 1. Body weight increment of shrimp in bi-culture system.

Significantly lower survival of shrimp the treatments where it was cultured with crab (Table 2) might be due to predation and competition for similar ecological niches. Borremans and Redant (1983) conducted a short time laboratory experiment under controlled condition and observed that about 2% of shrimp was being eaten by predatory nature of swimming crab, *Macropipus holsatus*. However, the survival rates of shrimp in bi-culture with crab are consistent with highly variable survival rates (30-70%) in shrimp culture that have been reported by different authors (Apud *et al.* 1984, Islam *et al.* 2005). Significantly lower survival in crab has been observed, in the present study, with the consequent increase in stocking density resulting in more cannibalism in crab. Mortality of crab due to cannibalism has been widely documented, particularly during and after moulting (Srinivasagam *et al.* 1984). Mortality due to cannibalism is common when mud crab is cultured at high stocking densities. Allan and Fielder (2004) reported survival rates of 80%, 45% and 32.9% at pond at stocking densities of 1, 2 and 5/m^2. In the present study, the lower survival in crabs might be caused due to low salinity in the last two months of the experimental period. However, this level of survival for crab in polyculture is not uncommon. In a polyculture trial carried out in earthen ponds with milkfish (*Chanos chanos*) and mullet (*Liza macrolepis*), the survival of mud crab was recorded as 26-30 % (Srinivasagam and Kathirvel 1992). While the production of shrimp (424.09±3.49 kg/ha) in monoculture (TI) was significantly ($p<0.05$) higher than that of 302.48±3.38 kg/ha in T2 and 323.27±9.68 kg/ha in T3, both bi-culture treatments of shrimp and crab (T2 and T3) resulted in similar ($p>0.05$) rate of shrimp production. This indicates that there might have been some degree of predation, but the stocking density of 0.5 or 1/m^2 of crab could be used in bi-culture with shrimp, without any significant reduction in shrimp production. In polyculture ponds, stocking rate of crab is being reported at 0.5-1.0/m^2 with 0.05-0.25/m^2 of milkfish fingerlings or 1-2/m^2 of shrimp (Quinitio 2004). Moreover, average production of shrimp obtained in the present experiment, either in monoculture or in bi-culture with shrimp, is quite higher than that of Apud *et al.* (1984), who reported an average yield of 340 kg/ha/crop at stocking rate of 4-5/m^2 in monoculture with supplemental feed and improved water management. The production of mud crab of 568.80 kg/ha was significantly ($p<0.05$) higher in T2 than in T3 where the production was 385.37 kg/ha. This level of crab production is quite comparable to the reported production of 292-690 kg/ha (Chaiyakaran and Pamichsuka 1978, Marichamy *et al.* 1980) at a similar stocking rates.

Conclusion

Growing crab with shrimp (*P. monodon*) and different brackishwater finfish species could be a technique for diversification of coastal aquaculture. In coastal areas of many countries, *P. monodon* and naturally collected crab seed are stocked with natural shrimp and they are reared mostly without feeding, fertilizers and liming are supplied in most farms with a mixed shrimp and crab productions of 425 ±102 kg/ha/yr and 107 ± 98.8 kg/ha/yr, respectively (Minh *et al.* 2001). In controlled polycultre system of shrimp (*P. monodon*), crab and finfish the crab and shrimp production could be much higher, as has been found in the present study and reported elsewhere (Marichamy *et al.* 1980, Samarasinghe *et al.* 1992, Allan and Fielder 2004). The intensive farming of mud crab has been found to yield as high as 1.5 t/ha, for each crop of 4-6 months, with an individual weight of 300-450 g (Thach 2004). However, the cannibalistic, predatory and burrowing nature of mud crab (Baliao *et al.* 1981, Cholik and Hanafi 1992) should be controlled to minimize losses and to make the crab culture profitable. In the present study, bi-culture of shrimp and mud crab seems to be feasible in brackishwater pond conditions. Proper food management may resist/minimize the predatory and cannibalistic behaviour of mud crab. However, further research is needed to improve survival rates of both shrimp and crab in bi or polyculture system.

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